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A MULTIPARAMETER DATA ACQUISITION AND DISPLAY PROGRAM

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ABSTRACT

A general purpose multiparameter data-acquisition, histogramming and display program is presented. The 32 input parameters of the program consist of up to 16 CAMAC words of 16 bits, and up to 16 algebraic functions of these words. Up to 64 one and two-dimensional histograms based on these parameters can be constructed, subject to up to 144 correlated conditions imposed on the input parameters. The display system consists of a rapid refresh scope with 10 bit X and Y resolution, and a push-button panel, specifically designed to interact dynamically with either the display or the data acquisition programs. Typical event rates vary between 300 Hz and 10 kHz, depending on the number of histograms generated and on their filtering conditions.

I. INTRODUCTION

The multiparameter data acquisition and display program described here was developed at the Los Alamos Van de Graaff facility, to serve the needs of a variety of low energy nuclear physics experiments. Although many concepts of the program were in application on a single user XDS-930 computer, its present version has been written for the three MODCOMP IV/25 - CAMAC interfaced-computers, currently in use at the facility.

The program consists of three tasks, communicating with each other through parameters in common data blocks. One task (MUL) acquires the data through CAMAC and accumulates the requested histograms. An other task (DREF) refreshes the display of the data, dynamically operates on the various filters and summing gates applied on the histograms, and interrogates, at 30 Hz, the status of a push-button panel. This panel was specifically designed to facilitate the interaction of the user with his data. A third task (DUPD) updates the buffers to be displayed.

The data structures used by these tasks are defined and managed by the general purpose data acquisition and analysis code[1] "Σ". These structures have been designed to optimize the speed of the data acquisition and display while keeping a general and dynamic character to the program. The three tasks of the program are set-up, activated or deactivated by the code "Σ", but run otherwise as asynchronous tasks. All these tasks run under the MODCOMP MAX IV operating system.

II. THE MULTIPARAMETER DATA ACQUISITION TASK MUL

The raw input data to the program are acquired by executing a list of CAMAC reads commands, stored in an instruction stack of the CAMAC Differential Branch Highway Driver[2]. The execution of the list is event triggered. A circular chain of three buffers, the length of which can be selected by the user, is filled through the direct memory processor (DMP) connected to the CAMAC Branch Dirver. When a buffer is full, the DMP causes an end of block interrupt to the computer, and the interrupt service routine schedules execution of the MUL task. The end of block service routine executes in less than 50 μs. It typically then takes 100 μs before the MUL task starts execution.

The program MUL recognizes the following elements:

Real ADC's

The raw data constituting an event consist of up to 16 CAMAC words of 16 bits. To each of these words, the program associates an item, called Real ADC (RADC), defined in the data structures by a descriptor word containing:

a) A 4 bit type defining a particular CAMAC input module: LRS register, EG&G ADC, etc.

b) A 4 bit mask number defining the most significant bit of the data word.

c) A 4 bit shift count used to prescale the RADC word to the desired number of significant bits.

A typical set-up command is:

RADC 1 ORTEC 1024 256

which defines one 16 bit word, originating from an ORTEC 800 ADC which has a conversion gain of 1024 channels full scale, and is to be scaled down to a maximum size of 256.

Pseudo ADC's

Up to 16 additional parameters, called pseudo ADC's (PADC) can be defined in the program. Their values may be constructed from the RADC values defined above and other PADC values. Each pseudo ADC is defined by a descriptor word containing:

a) a three bit type defining the operation to be performed. If A and B are real or pseudo ADC values, a and b are scaling (16 bit) fractions in the range ± 31.999 and n is 16 bit integer, the following pseudo ADC's can be constructed:

$(A+n) \cdot a$	Type 0
$(A+a \cdot B) \cdot b$	Type 1
$(A \cdot B) \cdot a$	Type 2
$A/B \cdot a$	Type 3
$(A^{1.73} - B^{1.73}) \cdot a$	Type 5
A user defined FORTRAN function	Type 7

b) a three bit mask number to determine the most significant bit of the PADC word.

c) the 5 bit index defining the element A of the above described functions as an item in the 32 word array of real and pseudo ADC's.

d) the 5 bit index defining the element B of the PADC operation.

A set of 2 scaling fractions and of 2 constants is available for each PADC operation. These variables can be changed while the program is running. The $A^{1.73}$ operation is done by table look-up.

The following commands would define two pseudo ADC's for mass identification as functions of two real ADC's, R2(E) and R1 (ΔE), obtained from a counter telescope.

PADC R 2 ADD .1 R 1	(Type 1)
PADC P 1 MASS R 2 .75 512	(Type 5)

In the first PADC command the sum E + .1 ΔE is formed, which presumes that the ratio of the gains of the ΔE and E ADC's is 10 to 1. The second PADC command scales the result of the "MASS" operation by a factor of .75, and limits it to a maximum value of 512.

Histograms

Up to 64 histograms can be maintained by the MUL program. The characteristics of each of these histograms are defined in two descriptor words, with the following subitems:

a) An 8 bit data area number to hold the histogram, defined by a memory allocation command of the program "Z".

b) A 4 bit mask number to determine the maximum value of the X or Y axis of the histogram.

c) A 4 bit histogram type. The 4 types currently supported are:

16 bit per word, one-dimensional histogram

32 bit per word, one-dimensional histogram

16 bit per word, two-dimensional histogram

8 bit per word, two-dimensional histogram

d) a 5 bit index defining the RADC or PADC value to be used for the X coordinate of the histogram.

e) A shift count to scale the X ADC value to match the size of the histogram.

f) The index and shift count to define the Y coordinate in a two dimensional histogram

The histograms and the data area numbers to hold them are defined by simple commands of "Z". For example the two commands

AME 10 1 4096 I*2 ΔE-E

MPD 10 R 1 P 1

set-up a 64 x 64, 16 bit, two-dimensional area with the identification number 10 and the label ΔE-E, and declare that the real ADC #1 (R1) will be used for the X coordinate while the pseudo ADC #1 (P1) is used for the Y coordinate of the histogram.

Filters

Each of the histograms can be subject to filter conditions, that is accumulated only if selected parameters in the event have values within specified limits. Information about which of the 144 possible filters may be active for a particular histogram is maintained in the 144 bits of 9 gate descriptor words attached to each histogram. The bit position in these descriptor words is used as an index into the filter limit arrays, defined in conjunction with display of the histograms. The filters can be activated or deactivated while the program is running. The parameters for the X and Y coordinates of the histograms can also be redefined dynamically.

Anti-filters

Up to 8 "anti"-filtering conditions can be applied to each event prior to placing the event in a tape buffer or prior to processing the requested histograms. This feature is useful to reject the entire processing of events falling within the range of specified limits, or scale down their processing to a certain fraction of these events (elastic peaks, for instance). The use of the anti-filters may be ANDed, and reject an event only if all anti-filtering conditions are met, or they may be ORed, that is reject it if any one of the conditions is met.

Event Processing

Upon being activated by the end of block interrupt from the CAMAC-DMP hardware, the MUL task fetches the events from the input buffer and calls the event processing subroutine, which flow chart is outlined in Figure 1.

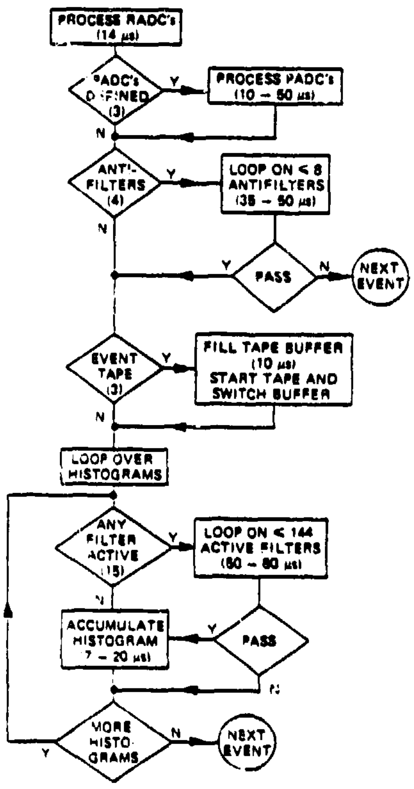

Figure 1. Flow chart of the event processing subroutine. The times given in parenthesis correspond to either a test or the processing of one item. When two times are given, they represent the variation due to the different types of item processed.

The data acquisition (or reprocessing) rates are variable. If an event consists of 3 real ADC's and if two two-dimensional unfiltered histograms are accumulated, together with a one-dimensional spectrum subject to 2 filtering conditions, the maximum event rate is about 10 kHz. In a program using 5 real ADC's, 16 pseudo ADC's, 25 filtering conditions and where 25 histograms are accumulated, the maximum event rate is ~ 300 Hz.

The size of the MUL task, excluding the histogram area, is 3416 words.

III. THE DISPLAYS TASKS AND CONTROL

The display refresh task DREF is activated by executing a stack of CAMAC instructions, reading and writing to a specially designed push-button control panel, and driven by a 30 Hz clock. DREF starts the direct memory transfer of a chain of 4 buffers to the scope. These buffers contain:

a) the image of a one dimensional spectrum, or a two dimensional spectrum, or a two-dimensional contour plot, or a three dimensional isometric display of the data.

b) a text of information such as run number, histogram title, peak centroids and number of counts, etc.

c) the image of 3 cursors. The cursor coordinates are updated, at 30 Hz, following joy-sticks on the display control panel.

d) a screen overlay in which the user can format any information of interest: additional labels, fits, kinematic contours etc.

The task DREF also decodes the status of lighted push buttons of the display control panel, if it has changed, and returns the decoded values to a common data block. It scans the list of assignments of the various buttons, and allows only valid combinations to be selected. If gate limits have been assigned to a particular combination, it varies these limits following the motion of the corresponding joy-sticks.

The display update task, DUPD is activated by a selectable timer (1s, 3s, 10s), or everytime a button on the display control panel is pushed and formats the scope buffers. Each CAMAC word transmitted to the scope has a 10 bit X coordinate, a 10 bit Y coordinate and a 4 bit intensity. The task DUPD also calculates the centroids, widths, sums and backgrounds of the selected one-dimensional gates, as well as the curves passing through the cursors of two-dimensional filters. Making a log display of a 1024 channel spectrum takes less than 100 ms.

The two display tasks DREF and DUPD use 18000 words of memory which includes 3600 words of display buffers. A large screen overlay buffer can be added to it by the user. The task DUPD consists of a root task and 4 overlays.

IV. DISPLAY CONTROL PANEL

The main features of the display control panel are the following groups of lighted push-buttons or switches:

a) Range: 16 buttons to determine the full scale coordinate in the range 64 to 2^{23} for linear displays, or 10 to 10^{16} for log displays.

b) Subgroup: 9 buttons to select the display region of a spectrum (full, halves, quarters, zoom around a peak).

c) Joysticks: 5 joy-sticks to control the upper and lower limits of intensified regions (gates) of one-dimensional spectra, the positions of cursors on the screen, or the line of sight with isometric displays. Each of the parameters acted upon by these joysticks can be varied in units of 1 to 10, depending on the status of a 10 position speed switch.

d) Spectrum Set and Spectrum: Three buttons are reserved to define up to 7 sets of histograms and 16 buttons to define up to 16 histograms within a set.

e) Gate Sets and Gates: To each histogram selected by the spectrum set and spectrum combination, one can attach sets of gates or filters, (pairs of limits for one-dimensional data, sets of curves for two-dimensional data). Three buttons allow the definition of up to 7 gate sets, and 16 buttons allow the choice of up to 16 gates per set.

f) Cursor Sets: Four buttons allow the selection of up to 15 sets of 3 cursors. For each set, curves are calculated to join the 3 cursors. These curves are 3 term polynomials, whose exponents are selectable by the user (usually hyperbolas or parabolas are chosen).

For one dimensional data, a cursor set will define a background. The user has the choice of constant, linear, parabolic, exponential or no background. For two dimensional data, a pair of adjacent cursor sets defines a region of the data to be used as a two-dimensional filter (gate).

Other buttons on the panel allow the selection of linear or log displays, overlays of spectra, the display of CAMAC scaler contents, or the grouping in blocks of 1024 for large one-dimensional histograms.

Display Set Up and Filter Commands

The histogramming routines of the data acquisition task MUL are linked to the display with commands closely associated with the configuration of the push buttons of the display control panel.

Typical display commands are:

DS 10 2 1 3 5 1

DS 11 1 2 1 1 4

The first command assigns histograms 10, to spectrum set 2, spectrum 1. This histogram has 3 gate sets of 5 gates each, with one cursor set to define backgrounds. The second command assigns histogram 11 to spectrum set 1, spectrum 2. This histogram has 1 gate set of 1 gate, and 4 cursor sets. The 4 cursor sets allow the definition of 3 filters (bounded by 4 curves passing by the 4 cursor sets) in a two dimensional histogram. The histogram type is linked to the histogram number when the memory area is defined.

Typical filter commands to be imposed on histograms are:

SFI 10 1 2 1 1 2

SFI 11 2 1 3 2

The first command sets a two-dimensional filter (SFI) on histogram 10. This filter is defined by the spectrum set 1, spectrum 2, gate set 1, gate 1 and cursor set 2 of the panel. Pressing this button combination would display histogram 11, and allow the variation of the gate limits selected. By convention, the filter is defined as the region bounded by the curves passing through cursor set 2 and cursor set 3. The second command sets a one dimensional filter on histogram 11. This filter is defined as the region of histogram 10 (spectrum set 2, spectrum 1) bounded by the limits assigned to the gate set 3, gate 2. Anti-filter commands are similar.

V. CONCLUSION

The close linkage of the display control panel and the histogramming of the data provides a precise, unambiguous and rapid mean of either enabling, disabling, or monitoring the data acquisition and filtering. The general purpose of the code (at the expense of some speed of processing) makes this dynamic scheme quite attractive. This data acquisition and display code has been in operation at the Los Alamos Van de Graaff facility since 1977. It has so far served the needs of experiments as different as (p,γ) reactions, tritium induced fission, $(^{14}C,^{18}O)$ reactions, (t,p) reactions and polarization studies.

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